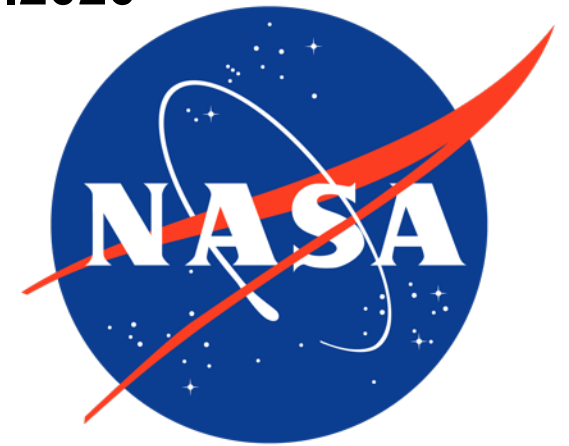


Integrated Battery Systems for Electrified Flight

NASA Electrified Powertrain Flight Demonstration – 11.30.2020



Presented by: AK Srouji, PhD - CTO



Engineering Overview

Strong team with relevant combined experience across key engineering disciplines

Romeo Engineering Overview

- 60+ battery-specific engineers
- Deep knowledge experts team across all core engineering disciplines including electrical, thermal, chemical, mechanical, electrochemistry
- Team members experienced with multiple prolific vehicle launches
- Combining automotive, space, and aviation tech to create the most advanced battery systems for electric vehicles
- 7 GWh-capable, fully functional manufacturing and R&D center located in Los Angeles, California

Representative Product Launch Experience of Romeo Engineering Team



Tesla Roadster



Tesla Model S



Tesla Model X



Faraday Future FF91



Fiat 500e



Porsche Cayenne Hybrid



Apache Helicopter



SpaceX Dragon Rocket

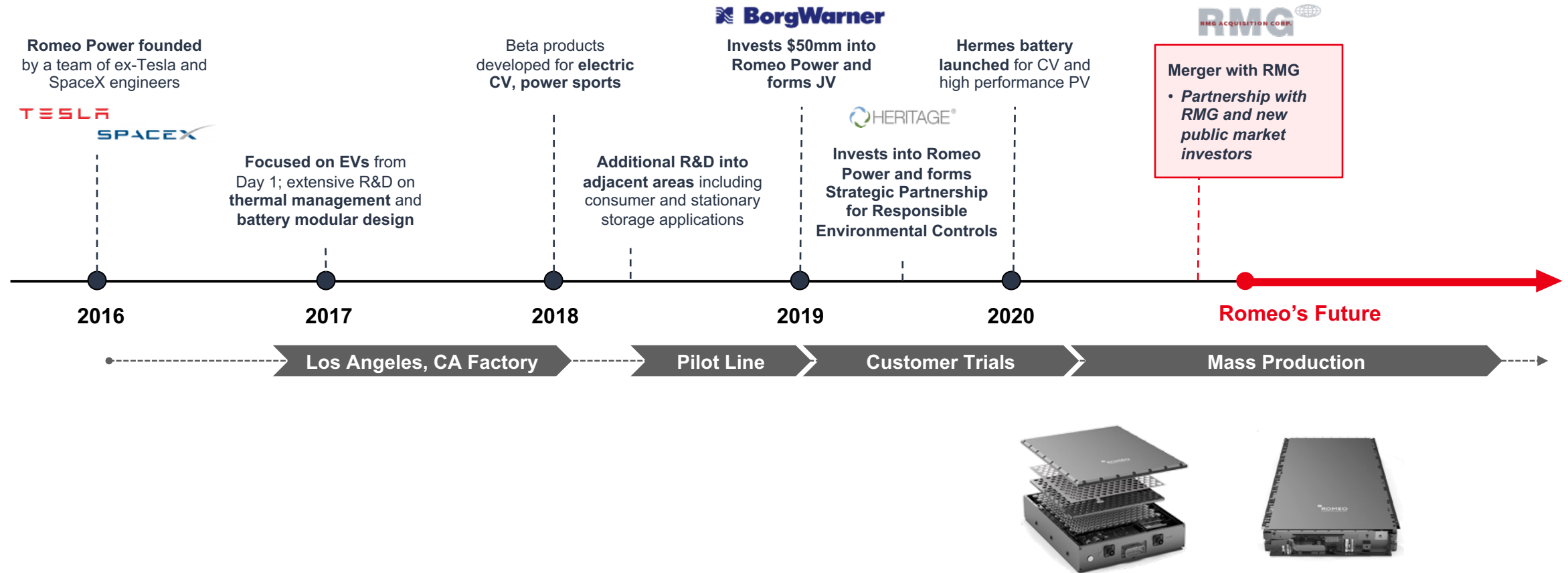
Select Professional Experience



Evolution of Romeo

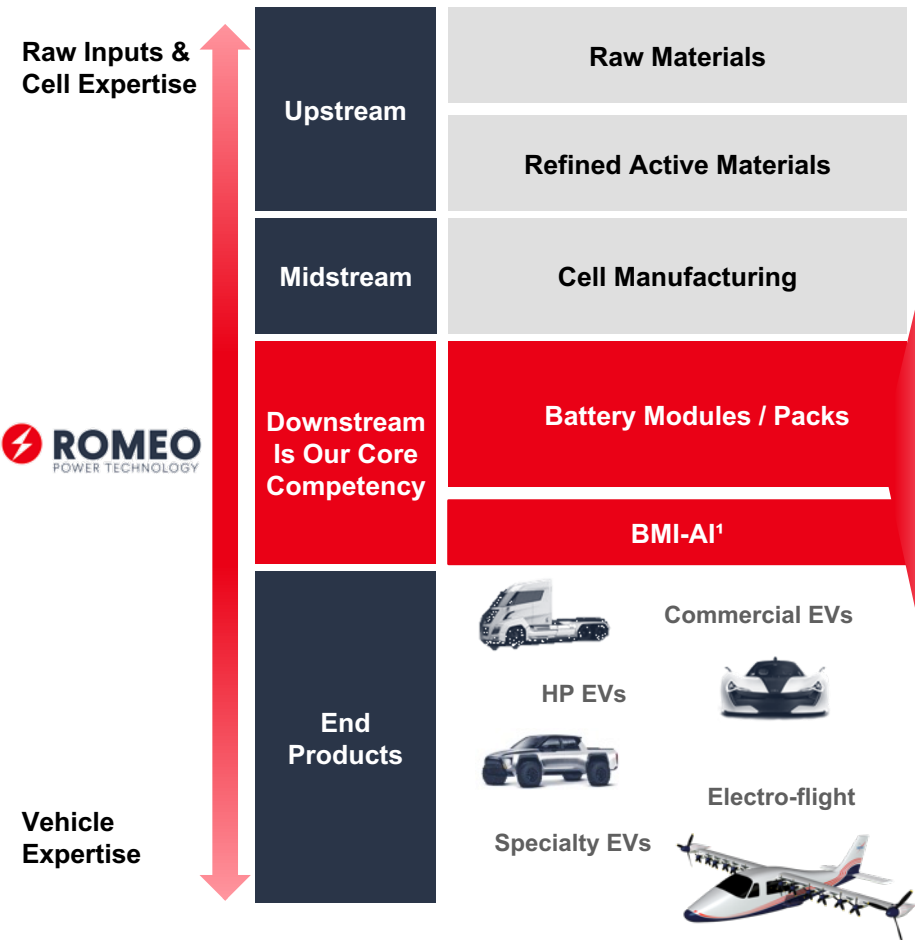
Demonstrating major milestone achievements and progress on vision in less than four years

Romeo's Evolution and Growth Trajectory



Core Focus on Battery and Module Packs

Battery Engineering



How Does Romeo's Technology Enhance EV Performance?

Cell Science Design and Engineering

- Romeo performs extensive independent evaluation of cells and closely collaborates with industry leading cell manufacturers at early development stages of next generation cell technology
- Cell selection process based on energy density, quality and safety standards

Modular / E-Plate Technology & Electro-Mechanical Engineering

- Designed for durability and crashworthiness; fulfills requirements for volume production such as manufacturability and serviceability
- Modules are designed to meet the highest safety standards and have undergone extensive testing and broad-based customer validation

Thermal Engineering

- Designed for consistent temperature distribution within and among all battery cells guaranteeing lifetime maximum battery performance

Battery Management System (BMS)

- Creates a singular platform enabling all customers to benefit from field testing of electronic and software for prototypes through scaled deployment
- Established safety measures system, including isolation monitoring, high voltage interlock, manual service disconnect, hardware and software protections

BMI-AI¹

- Maximize total fleet battery health by leveraging machine learning to help reduce total cost of ownership
- Learn aging factors from field behavior based on feedback from battery population health optimization
- Provide individual decisions that benefit net total asset and increased profitability of fleet managers, and total cost of ownership



Mass Production

¹ Brain Machine Interface - Artificial Intelligence

State-of-the-Art Production Facility

In-house design, manufacturing and testing capabilities for Romeo North America

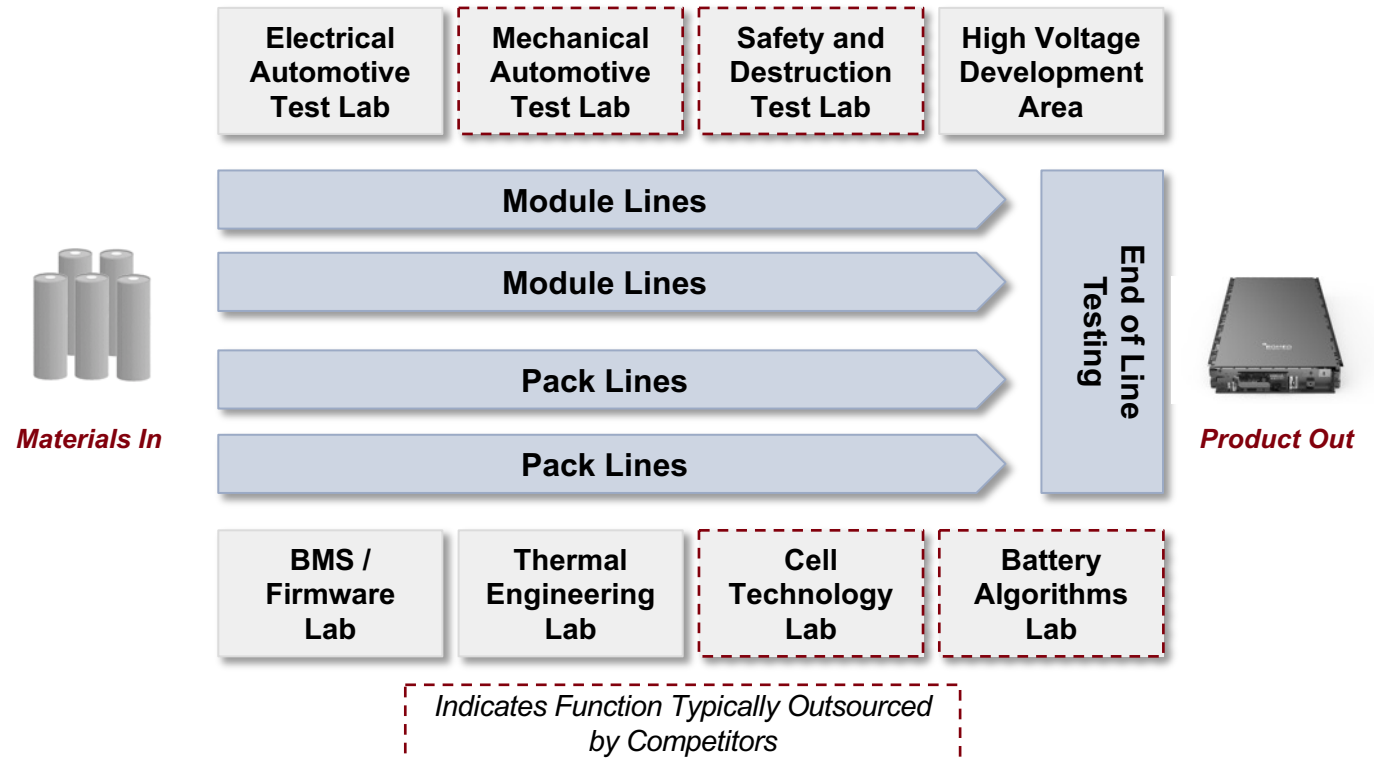
Site Highlights

- 113,000 ft² North American Headquarters, strategically located in Los Angeles to attract the best industry talent
- Deliberately designed to allow for cost effective expansion of productions lines to 7 GWh / year capability
- All key battery development labs in-house, including:
 - Reliability, Testing & Validation Lab
 - Battery Cell Test Lab (Form Factor Agnostic)
 - Battery Safety & Test Facility Section
 - Battery Management Systems Engineering
- ISO9001 Certified & UL2580 Certified¹

Production Facility Outside of Los Angeles



Romeo Facility Overview



While many competitors outsource most testing and some assembly, Romeo's complete in-house solution-set allows the company to protect IP, ensure quality control and accelerate development and production

¹UL 2580 Certified BR Module & Thunder pack

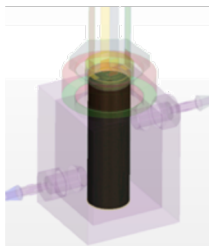
Technology Overview

Romeo's batteries use a modular design and best-in-class components

1

Cell Science

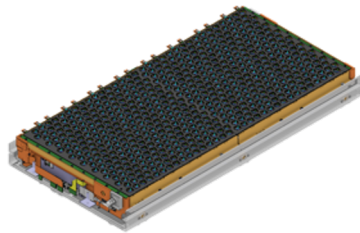
- Cell procurement is a carefully guided process with rigorous testing and validation processes to ensure only the best cells are selected
- Romeo's packs and modules are cell-agnostic, allowing the company to use only the best for each application, and adapt and change as new cells come to market



2

Module Technology

- Flexible and customizable design acts as a building block which allows for custom packs without needing months / years of additional R&D for each prototype
- Modules are designed to meet the highest safety standards and have undergone extensive testing and broad-based customer validation, both at the individual pack and module level



3

Pack Technology

- Mechanical pack design addresses key requirements – from durability and crashworthiness to manufacturability, serviceability, and recyclability
- Flexible design allows the company to reach significant scale and a broad range of customer needs without incurring significant additional costs and overhead



4

BMS

- Battery management system serves as complete solution for monitoring and control
- Romeo's BMS are built on a highly configurable platform, allowing it to support a wide variety of architectures, and driving lower cost and a faster time to market when compared to peers



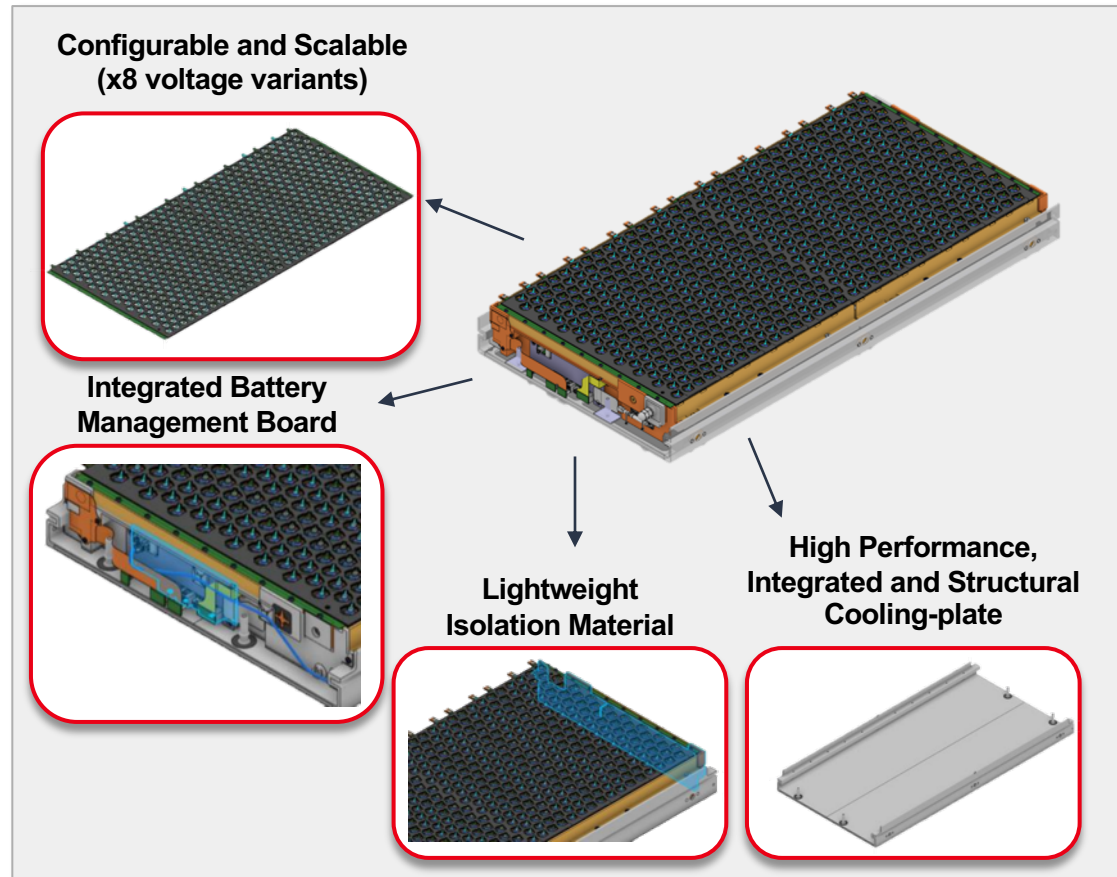
Exhaustive Testing In-House

Developed by Romeo In-House

Module Technology

Flexible and efficient building block for configurable, scalable energy storage

Hermes Module



Key Attributes

- **Market-leading building block** with active high cooling performance
- **20-30% more energy density** than same-size competitor packs ¹
- High stability and **superior thermal management** (<4 °C Temp delta)
- Patented and structural cold-plate technology allows for **quick integration into vehicle structures**.
- **Electrical isolation protection achieved without compromising** energy density or thermal performance 1000V working voltage.
- Liquid active cooling within **slimmest volume factor** (7% of volume)
- **No fire propagation** during single or multiple cell failures
- **2hr baseline charge time** for optimal life (20min, fast charge to 80%)
- **Highest manufacturing rate** at <100 ms per Cell



¹ Management estimate

Battery Management System (BMS)

Among the most flexible and configurable systems in the market today

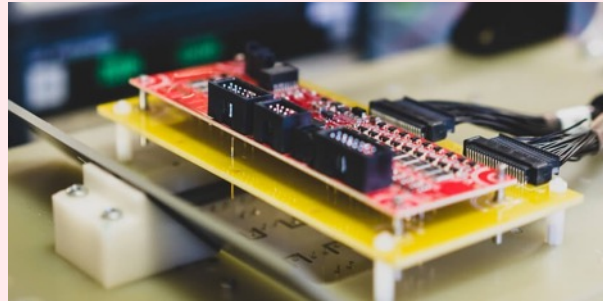
Romeo's BMS offers a complete solution for monitoring and controlling complex battery systems for automotive applications

Features

- Voltage, current, temperature, isolation measurements
- Operating modes, contactor, pre-charge and charge control
- Safety measures – isolation monitoring, high voltage interlock, manual service disconnect, hardware and software protections
- Advanced battery control algorithms
- Advanced diagnostics and prognostics
- Field configurability for fast and convenient integration
- Support over-the-air updates
- Cybersecurity
- Automotive ISO 26262 compliant¹



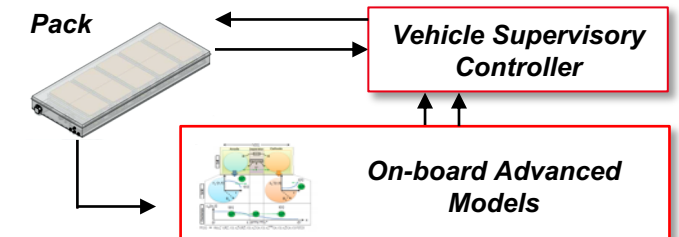
Value Proposition



- **Built on highly configurable platform**
- **Self-diagnostics**
- **Supports wide variety of architectures**
- **Operates with virtually every vehicle engine control unit**
- **Proven exceptional real world performance**
- **Low cost and robust**
- **Scalable from 48V to 1000V**
- **Faster time to market**

Advanced Algorithms

- Others only measure voltage, temperature and current, leading to increased buffers and cost
- Romeo utilizes a series of sophisticated real-time onboard models as a result of proprietary testing and algorithm developments:
 - More accurate remaining range estimation
 - More accurate battery health estimation
 - Enables safer and faster charging



¹ISO 26262 compliance is not yet complete, but expected by Q2 2021

Thermal Event Safety

Designing a safe battery system using a collaborative effort across multiple knowledge domains

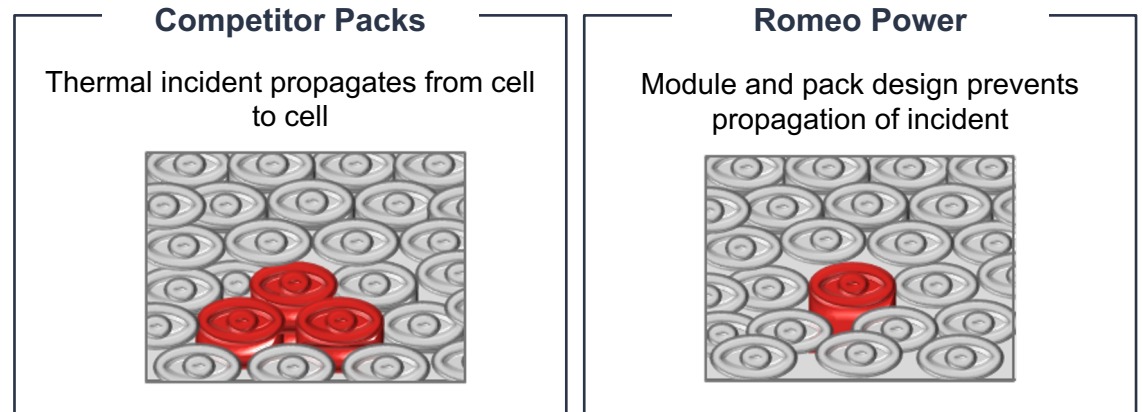
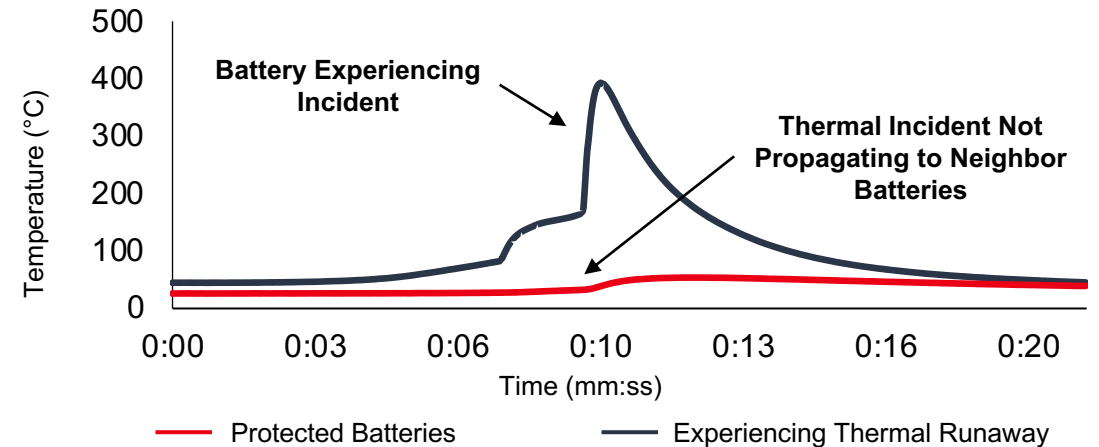
Thermal Event Mitigation

Cell Selection	Electrical Design
<ul style="list-style-type: none">• Selection of safest cells only as result of elaborate testing campaign• Reproducible and predictable behavior	<ul style="list-style-type: none">• Rational fusing hierarchy down to the single cell• Multiple disconnects and pyro devices
Mechanical Design	Pack Design
<ul style="list-style-type: none">• Robust to vibration and road failures• Flame ablation and resistant material	<ul style="list-style-type: none">• Venting strategy and methodology• Crash mitigation strategy

In-House Battery Safety Testing and Targeted Safety R&D

- Allows for continuous destructive testing and failure analysis, providing quick and precise feedback for the safest product designs
- In-house testing capabilities include:
 - Cell, module, pack and destructive testing (fire and mechanical)
 - Materials and components stability / dielectric withstand at high voltage
 - Testing and validation of venting strategies
 - Abuse testing covers most stringent safety standards
- Safety group director with 10+ years of battery safety experience

Romeo's Solution at Work



■ Experiencing Thermal Runaway

Pack Technology

Customers are willing to pay a premium for integrated products from their battery solution provider

With Just One Highly Configurable Module...

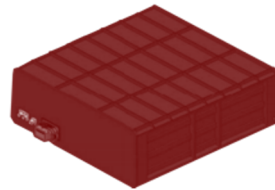


Hermes Module

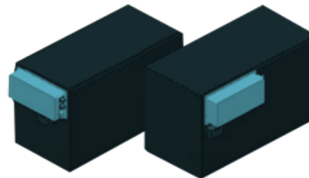
... Romeo Can Create a Variety of Unique Packs...



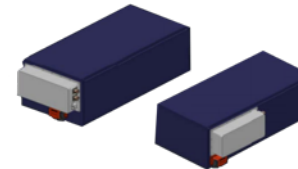
Orion V4



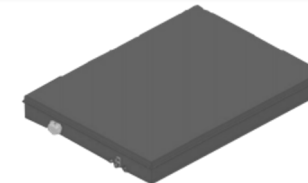
Orion V3



Orion V2



Orion V1



Flat V2



Flat 1

... Serving a Wide Range of Growing End Markets¹



Freight



Bus / Shuttle



Refuse Truck



Delivery Truck

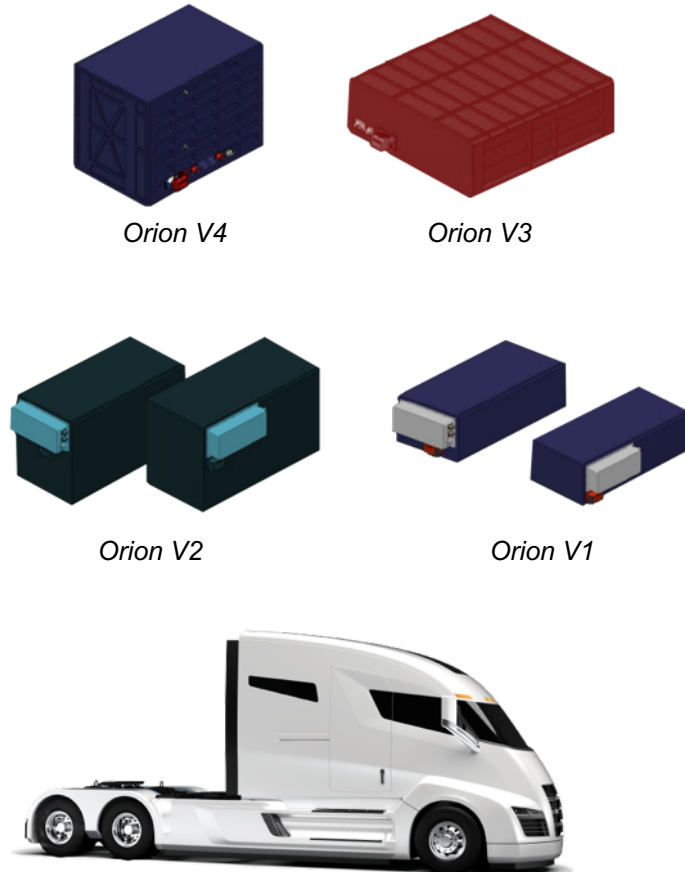


Using 4 major cells, with 8 voltage variants and 6 different packs, Romeo is able to create 192 products utilizing the same module, manufacturing line, process and test sequence, allowing for high customizability and product expansion with ease

¹ Representative only, non-exhaustive list of potential end markets or offerings. Romeo does develop more than one module in-house

Pack Technology for E-Flight

Taking advantage of product status for trucks and commercial vehicles

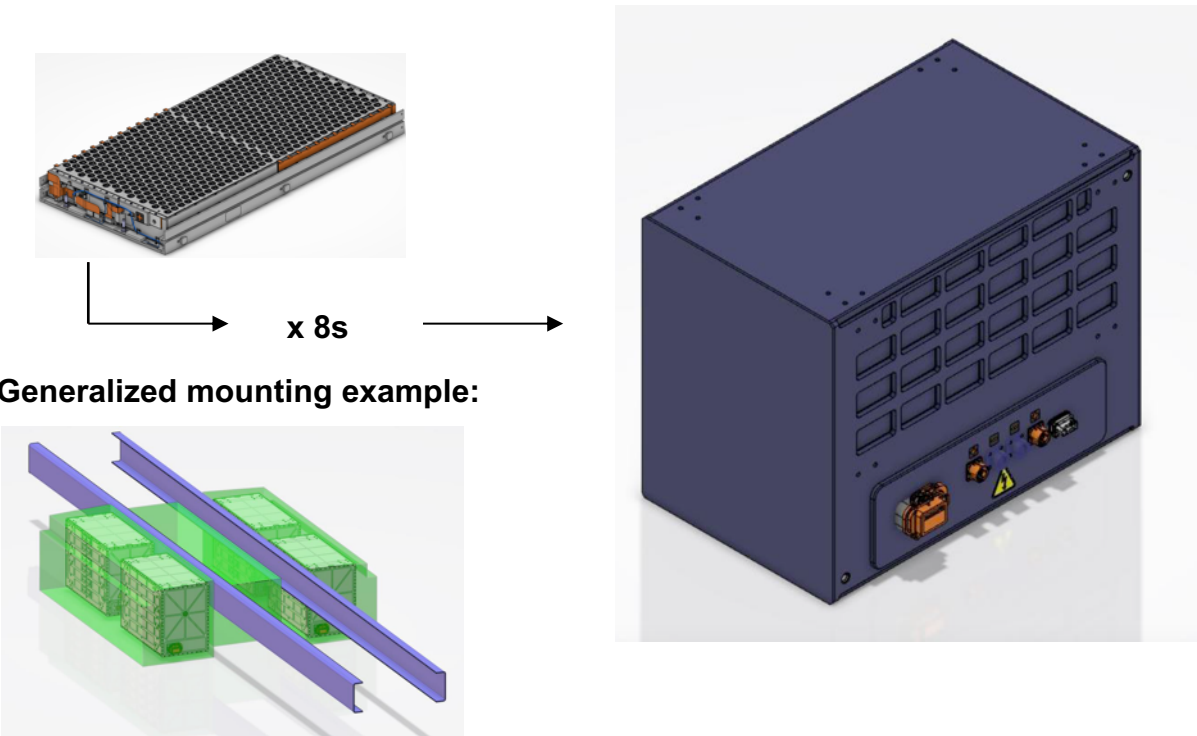


- **Reduce Weight:**
 - Increase structural integration
 - Utilize more lightweight materials (composites, hybrids, etc)
- **Increase Power**
 - Cells with high P/E ratios
- **Evaluate and upgrade as needed for aviation grade redundancy and functional safety**
- **Other**

¹ Representative only, non-exhaustive list of potential end markets or offerings. Romeo does develop more than one module in-house

Example Mega Pack

- 1.2 MWh system to achieve 900+ km
- 7+ yrs, 700,000+ km life
- Distributed system w/ ISO 26262 BMS
- Serviceable junction per pack box for ease of maintenance and access
- Single or multiple cell fault tolerance at pack level
- SAE J2380
- Temperature uniformity within 3 dimensions < 5 deg C
- Scalable system allows to add/remove energy for specific customer needs



Single Pack		System Level	
Application		Mega EVs	
Configuration		8S1P (Hermes 24s)	1S15P Parallel Packs
Capacity:	Total	80 kWh	1.2 MWh
	Useable	65.6 kWh	1 MWh
Voltage Range, Operation		806 to 480 VDC	
Cont. Power	1.2C (approx. 96 kW) discharge	1.2C (approx. 1440 kW) discharge	
	0.9C (approx. 72 kW) charge	0.9C (approx. 1080 kW) charge	
	0.31 C (approx. 25 kW) regen	0.31 C (approx. 375 kW) regen	
Peak Power (10 sec pulse)	4C (approx. 320 kW) discharge	4C (approx. 4.8 MW) discharge	
	3C (approx. 240 kW) regen	3C (approx. 3.6 MW) regen	
Operation Temp		-20 to 60°C (discharge) 0 to 50°C (charge)	
Dimension (overall)		844 (L) x 671 (W) x 714 (H) mm per Pack	
Volume		404 L	6,060 L
Volumetric Energy Density		200+ Wh/L (up to 245 Wh/L)	
Weight		Less than 500 kg	Less than 4,500 kg
Gravimetric Energy Density		Greater than 160 Wh/kg	
BMS Architecture		Distributed with CANbus Communication Over J1939	

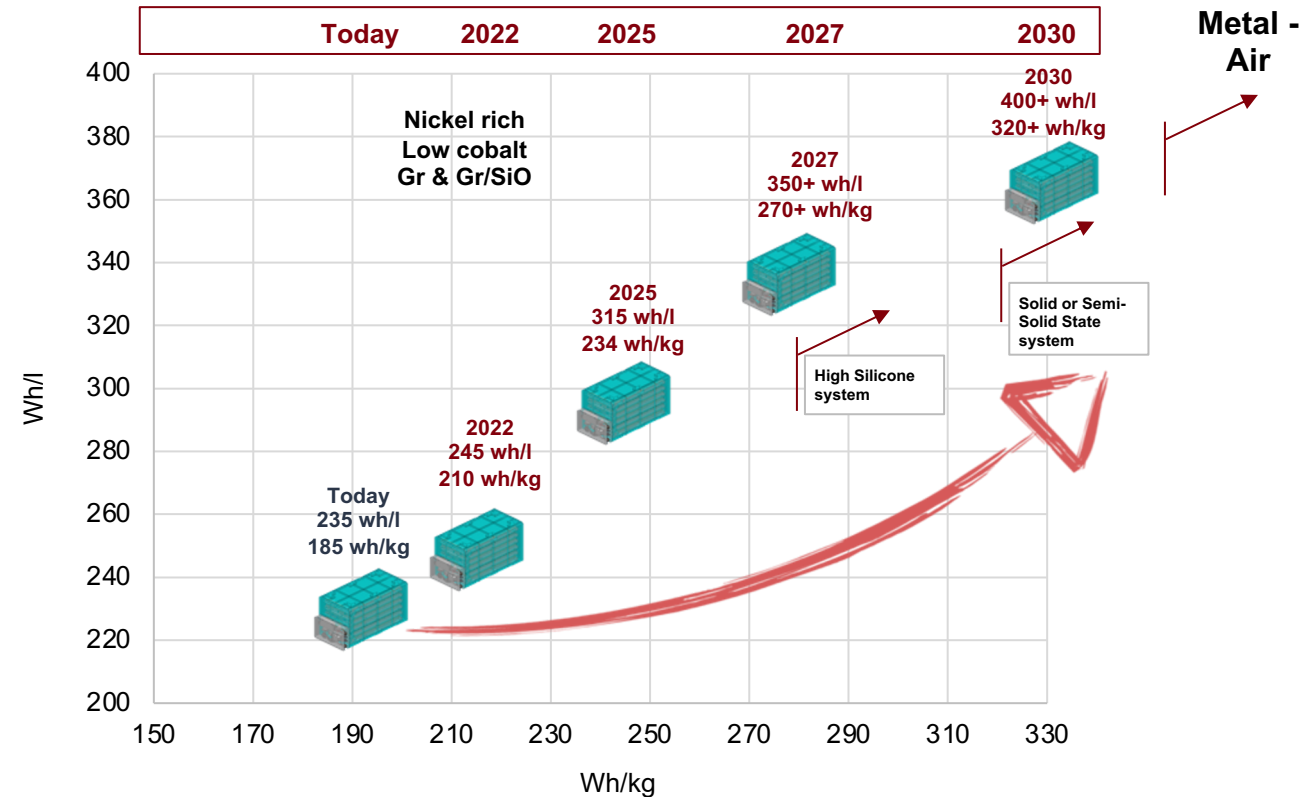


Reducing weight, Increasing Power to Weight Ratio are in Focus



- **Reduce Weight:**
 - Increase structural integration
 - Utilize more lightweight materials (composites, hybrids, etc)
- **Increase Power**
 - Cells with high P/E ratios
- **Evaluate and upgrade as needed for aviation grade redundancy and functional safety**
- **Other**

Energy Density Improvements Remain Critical



Defined Pathway with Continuous Potential Improvements Until 2030



¹ Energy density at pack level